Initial study - draft

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Measurements of heat transfer coefficient of external walls with different insulation materials

This study has two main goals: (i) to compare the heat transfer coefficient of external walls with two different insulation materials: wood fibres and foam-glass; and (ii) to evaluate the heat flux sensor as a tool for measuring heat transfer coefficient of buildings. Two case studies of detached houses were studied. Both are located in Juniskär, south of Sundsvall. The first case study is a wooden constructed detached house with wood fibre insulation material (Fig.1). The second case study is made of foam-glass elements, which perform as insulation material covered by wooden panelling (Fig.2). Both buildings have similar insulation thickness in the external walls of about 300 mm. The wood fibres and foam-glass have similar thermal conductivity; 0.041 W/(m K) and 0.039 W/(m K) respectively. These values were obtained from Åke Mård from koljern.

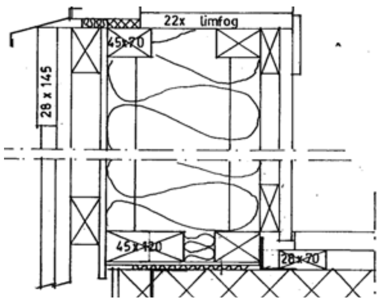

Figure 1 Case study of detached house with wood fibre insulation material

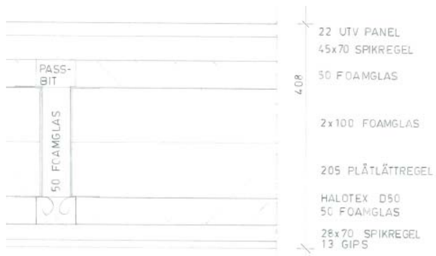

Figure 2 Case study of detached house with foam glass insulation material

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The heat transfer coefficient (U) of buildings elements is a coefficient of proportionality between the heat flux and the temperature difference between the indoor and the outdoor (ΔT). The heat flux is the product, while the temperature difference is the driving force. The heat transfer coefficient could be determined by regression analysis if the heat flux is known for a range of temperature differences between the two sides of the building element.

Measurements

The heat transfer coefficient of building elements can be calculated from measured values of heat flux and ambient air temperatures at both sides of the element, i.e. indoor and outdoor temperatures.

In this study, a heat flux sensor of type *HFP01 Hukseflux* was used. The sensor has a nominal sensitivity of 50 μV/Wm^2, a working temperature range between -30°C to +70°C, and an expected typical accuracy of ±5%. The sensor was connected to a logger of type *LI19 Hukseflux*. The measurements started at 2013-02-22 18:00 and ended at 2013-03-18 08:00 with 15 minutes interval between readings.

To obtain accurate measurement it was important to reduce the effects of external parameters to the minimum possible. In this study the following measures were taken:

- The heat flux was measured at the ground floor at the same height level in both case studies.
- The indoor temperature, in each case study, was measured at the same location as the heat flux.
- The heat flux measurements were done on the inner side of the north facing external wall in order to avoid the effects of direct solar radiation during day time.
- The walls were scanned with an infra-red camera (*Fleer T440*) to avoid locations with wooden studs, pipes, electrical wiring or any other installations that could have an effect on the results. A location with uniform wall surface temperature was chosen in each of the case studies.
- The heat flux sensor was coated with a high heat conduction layer (dow-corning gel) before attaching it to the wall. The gel reduces the heat resistance between the sensor and the wall by reducing the amount of air cavities.

A temperature sensor of type *RHTemp1000 MadgeTech* was used to measure the outdoor temperature. The working temperature of the sensor is between -40°C and 80°C, the temperature resolution is 0.1°C and temperature calibrated accuracy is ±0.5.The accuracy of the heat flux measurement can be affected by different parameters.

A temperature sensor of type *MicroRHTemp MadgeTech* was used to measure the indoor temperature in each of the buildings. The working temperature of the sensor

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is between 0°C and 60°C, the temperature resolution is 0.1°C and the temperature calibrated accuracy is ±0.5. The temperature sensor in each building was located at the same location as the heat flux sensor.

RESULTS

Temperature measurements

During the measurement period the outdoor temperature ranged between -17°C and +9°C, as illustrated in Fig.3. The indoor temperature, in the wood fibre case study house, was found to be less stable with several high picks, and was, in average, 5.5°C lower in comparison to the foam glass case study house. Thus, the difference in ambient air temperature between the indoor and outdoor (ΔT) was lower and with more fluctuations in the wood fibre case study house.

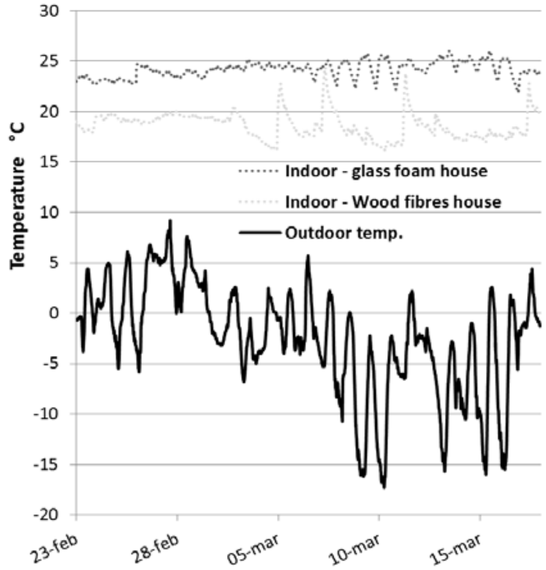

Figure 3 Measurements of the indoor and outdoor temperatures

Thermal properties

In Fig. 4 and Fig. 5, the measured heat flux values were plotted against the differences between indoor and outdoor ambient temperature for each case studies. The heat flux was found to increase with temperature differences, which was expected and the value of heat transfer coefficient, represented by the tangent of the trend line, was determined by a linear regression including all the measured values.

The heat transfer coefficient of the wall element in the wood fibre case study was found to be 0.1888 W/(m^2 K), which is higher by 38% in comparison to 0.1371 W/(m^2 K) as found in the foam glass case study house (fig.4 and fig.5).

The values of the thermal conductivity (**k**) of the insulation material in each of the buildings were calculated from the measured heat transfer coefficient (**U**), by knowing the wall construction in each case study (according to Fig.1 and Fig.2), and by using Eq.1, with ***h*** as the convection heat transfer coefficient for air. According to the results, the thermal conductivity of the foam glass case study house found to be 0.042 W/(m K), which is only 2% higher than the expected value. The thermal conductivity of the wood fibre case study house found to be 0.059 W/(m K), which is higher by 51% than the expected value.

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Eq.1 $$\frac{1}{U} = \sum \frac{1}{h} + \sum \frac{L}{k}$$

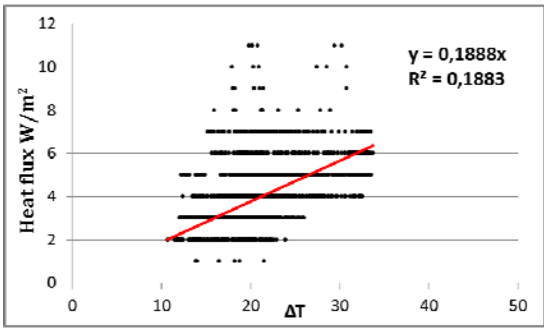

Figure 4 The heat flux and temperature difference measured at the wood fibre case study house

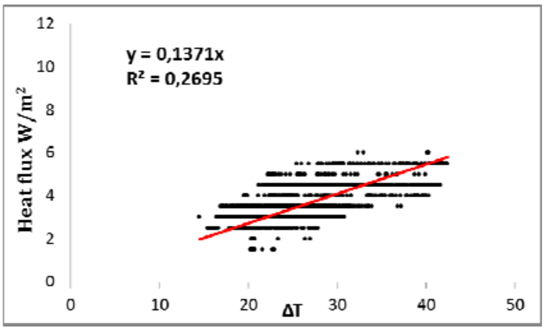

Figure 5 The heat flux and temperature difference measured at the foam glass case study house

Uncertainty

In a steady case condition, the heat flux is expected to follow a linear trend-line as the temperature difference changes. However, with frequent change in indoor and outdoor thermal conditions, steady state is seldom attained. Thus, large span of heat flux was measured for each ΔT, and relatively low coefficient of determination (R^2) obtained; 0.1883 and 0.2695, respectively for the wood fibre and foam glass case study houses. The low R^2 indicates that large uncertainty exists in determining the value of the heat transfer coefficient, and therefore its value should be taken with caution.

Conclusions

In this study the heat transfer coefficient of a building element (external wall) was determine by measuring the heat flux through the element and the difference in ambient air temperature between its both sides. This seems to be possible but there are three disadvantages to this method:

1. Several weeks might be needed to obtain sufficient sample size of heat flux measurement.
2. The heat flux measurement is a local measurement and does not represent the overall heat transfer coefficient of an entire building element. The measurement locations that were chosen were homogenous. Thus, the effect of wooden studs, corners, or other irregularities in the building elements, which could have a significant effect on the overall heat transfer coefficient, and are not considered in this study.

3. The results found to have large uncertainties as the indoor and outdoor thermal conditions changes frequently and a steady state heat flux, through the building element, is not a constant conditions.
4. The measured values of the heat transfer coefficient and the thermal conductivity for the foam glass case study house were in the expected range. However for the wood fibre case study house the measured values were higher than expected, as listed in Table 1 below. The causes for these high values need additional investigation.

Table 1. Comparison between the calculated (expected) and measured values

Case study building	Thermal conductivity		Heat transfer coefficient	
	Expected W/(m K)	Measured W/(m K)	Calculated W/(m^2 K)	Measured W/(m^2 K)
Wood fibre	0.039[1]	0.059[2]	0.122	0.1888
Foam glass	0.041[1]	0.042[2]	0.133	0.1371

[1] Values obtained from Åke Mård from the Koljern Company.

[2] Values calculated from the measured values of the heat transfer coefficient

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